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(54) **Gas turbine component**

(57) A gas turbine component consists of a super-alloy base material with a single crystal structure and a

protective coating layer. The coating layer has a single crystal structure, which is epitaxial with the base material.



**Description****TECHNICAL FIELD**

- 5 [0001] The invention relates to a gas turbine component in accordance with the preamble of the first claim.  
 [0002] It likewise relates to a method for protecting a gas turbine component in accordance with the preamble of the independent method claim.

**BACKGROUND OF THE INVENTION**

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[0003] Latest turbine experience clearly shows that mechanical properties of coatings are one of the most critical material issues in advanced turbines. Progress in blading materials and technologies (i.e. single crystal blading) is not followed by today coating systems. Thermo-Mechanical-Fatigue (TMF) properties of coated alloys are far below those for uncoated single crystal (SX) material. The main effort in increasing of the TMF life of the coated component concentrates now in two directions. The first is to fit the coating composition to the composition of the substrate. That minimizes the difference in thermal expansion between coating and substrate. The second is in providing a fine grain structure to the coating in order to increase ductility and therefore reduce stress accumulation due to the difference in mechanical behavior of the coating and the substrate.

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[0004] US Patent 4,758,480 discloses a class of coatings whose composition is based on the composition of the underlying substrate. The similarity in phase structure and in the chemical composition renders the mechanical properties of the coating similar to those of the substrate thereby reducing thermomechanically-reduced damage during service. However, when this coating is applied by traditional means on the single crystal substrate, the difference in the E-modulus between <010> oriented surface layer of the substrate and randomly oriented coating grains produce high TMF damage.

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[0005] US Patent 5,232,789 discloses the further improvement of the TMF properties of the coating-substrate system. The coating, which has composition and phase structure similar to the substrate alloy, has at least 1000 times more fine-grained structure, produced by a special technology. The lowermost interface portion of the fine-grained coating grows epitaxially, and therefore has the same crystal orientation as the substrate. Epitaxial growth solves also coating / substrate interface adhesion problem.

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[0006] However, the system of a single crystal substrate and the multicrystal coating still has a large difference in the mechanical behavior between the substrate and the coating as any equiaxed structure possesses E-modulus much higher than those for single crystal material in <001> direction. Higher E-modulus reflects in lower TMF life of the coating compared to the substrate (although the stresses on substrate-coating interface are significantly reduced compared to the traditional coating - substrate system). Multiple grain boundaries drastically reduce the creep resistance of the fine-grain coating, which finally determines life of the entire blading system.

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**SUMMARY OF THE INVENTION**

[0007] Accordingly, one object of the invention is to provide coatings which mechanical properties which are adjusted to the substrate and which have a high TMF life.

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[0008] According to the invention, this is achieved by the features of the first claim.

[0009] The core of the invention is therefore the fully single crystal structure of the coated gas turbine component, which with single crystall coating layer is grown epitaxially to the base material.

[0010] The advantages of the invention can be seen, inter alia, in the fact that a fully single crystal structure of the coated component, including a MCrAlY -type coating, grown epitaxially to the base material will minimise the difference in E-modulus and therefore in TMF life between single crystal substrate and the coating. The base material and the coating have the same crystallographic orientation and therefore E-modulus is almost constant over the substrate / coating system. Through optimization of the chemical composition of the coating it is possible to achieve very low mismatch in thermal expansion between coating and substrate. Creep properties of the epitaxial coating are made equal to those of the substrate by chemistry optimization, which is impossible for the system single crystal substrate - fine-grained coating. The entire system therefore will have mechanical properties close to those for the base material and the life - time is at least doubled compared to the traditional single crystal substrate - fine-grained coating systems.

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[0011] Further advantageous embodiments of the invention emerge from the subclaims.

[0012] Moreover, a method for protecting a gas turbine component is further specified.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

[0013] A more complete appreciation of the invention and many of the attendant advantages thereof will be readily

obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying pictures, wherein:

- Fig. 1 Schematic representation of a laser cladding process,  
 5 Fig. 2 Optical micrograph of base material coated with single crystal structure;  
 Fig. 3 Optical micrograph of base material coated with single crystal structure, higher resolution;  
 Fig. 4 SEM micrograph of coating;  
 Fig. 5 SEM micrograph of coating, higher resolution;  
 Fig. 6 SEM micrograph of coating, highest resolution;  
 10 Fig. 7 SEM micrograph of coating, different etchant;

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 [0014] A laser cladding technology has been used to apply an epitaxial coating with 100 - 300  $\mu\text{m}$  thickness on the single crystal superalloy substrate. Because the coating is epitaxially grown on the substrate, it has the same crystal orientation as the substrate.

[0015] In figure 1 a laser cladding process is shown which is characterized by impinging a metallic powder jet 1 onto a molten pool 2 formed by controlled laser heating by scanning the laser beam 3 successively over the substrate 4 (see the arrow showing the movement over the substrate), a two dimensional clad 5 can be deposited. This kind of technology is illustrated in figure 1.

20 [0016] In the example of figure 1 a CO<sub>2</sub> Laser has been used during the experiment. The supply material has been fed under protective gas like Argon.

[0017] US Patent 4,643,782 discloses a nickel base alloy with the trademark name "CMSX-4", essentially comprising (measured in % by weight): 9.3-10.0 Co, 6.4-6.8 Cr, 0.5-0.7 Mo, 6.2-6.6 W, 6.3-6.7 Ta, 5.45-5.75 Al, 0.8-1.2 Ti, 0.07-0.12 Hf, 2.8-3.2 Re, remainder being Ni with impurities.

25 [0018] A single crystal bar with <001> crystallographic orientation cast in alloy CMSX-4 was coated with MCrAlY-type coating, especially an NiCrAlY - type coating called SV20 by laser cladding with a 1,7 kW cw CO<sub>2</sub> laser in argon protective atmosphere, like it is shown in figure 1.

30 [0019] The SV-20 coating essentially comprising (measured in % by weight): 25 % Cr; 5,5 % Al; 2,7 % Si; 1 % Ta; 0,5 % Y, remainder being Ni.

[0020] Typical process parameters for growing the coating onto the substrate via laser cladding technology are as follow:

Laser Power	800 W
Laserbeam Diameter	2.8 mm
Laserscanning Speed	250 mm/min
Powder Feed Rate	2 g/min
Gas Protection	Ar 35 l/min
Preheating	none
Intertrack Step	0,9 mm
Treatment Length	4x37,5 mm
Powder Size	35-90 $\mu\text{m}$
Powder Efficiency	56 %
Final Temperature	300 °C
Processing Time	52'22"

35 [0021] A single crystalline coating was produced by epitaxial growth of the SV20 on the CMSX-4 substrate. In following the single crystalline SV20 coating produced by laser cladding will be called SV20 SX. The coated test bar was cut in longitudinal and transverse sections. Some of these sections were heat treated in inert gas at 1140°C for 4 hours.  
 40 This kind of heat treatment has as a purpose a diffusion treatment of the interface between coating and substrate, as well as homogenisation of coating and  $\gamma$ -phase precipitation heat treatment of the CMSX-4 substrate.

50 [0022] The transverse and longitudinal specimens in as deposited and heat treated condition were mounted, ground

and polished up to 1  $\mu\text{m}$  diamond paste for the metallographic investigation. For the fine microstructure and analytical investigation the samples were chemical etched according to the standard procedure for Ni-base superalloys. For the investigation of secondary grains the samples were newly polished and etched with the following etchant:

100 ml	H <sub>2</sub> O
100 ml	HCl
5 g	Cu(II)chloride (room temperature, time $\approx$ 10 s)

[0023] The etchants basically both attack Al-rich phases. The Cu(II)chloride etchant indicates different grains better. The microstructure was assessed with optical microscope, SEM, EDX analysis, digital image analysis and EBSD technique.

[0024] Microstructural analysis shows that dendrites 6 are created of the epitaxially grown coating on the base material 4 so that a single crystal structure is achieved (see figures 2, 3). Depending on the location of the sample periphery in the transverse cross section the main growth direction changes from the primary dendrite trunks to the secondary arms without change in the underlying crystal orientation. The micrograph shows a perfect epitaxial growth on the base material. Only the outer region of the coating has a different lattice direction as indicated by differently oriented dendrites. This polycrystalline region can be avoided by fitting the cladding parameters or by machining. The latter does not disturb the single crystalline product. The measured thickness of the various regions in the coating are as follows:

CMSX-4 remelting region	60 to 100 $\mu\text{m}$
single crystal region	400 to 550 $\mu\text{m}$
polycrystalline region	100 to 250 $\mu\text{m}$

[0025] Taking into account that the typical thickness of the coating on gas turbine blades and vanes is about 150 - 300  $\mu\text{m}$ , it is clear, that a fully SX coating can be provided even if the polycrystalline regions of the coating have to be machined away.

[0026] The SEM micrographs of figures 4 to 7 show the microstructure of SV20 SX in as deposited condition with increasing scaling factor from figure 4 to figure 7. The coating consists of 96 vol.% dendrites. The dendrites are single phase as far as the applied investigation method shows. The interdendritic space consists of at least two phases, which are the matrix (dark in the SEM images, fig. 4 to 8) and bright precipitates that surround chain like the dendrites (figure 5).

[0027] The interdendritic matrix possibly contains also very small other precipitates (figure 6) but this is not clearly visible in the SEM image. Furthermore the coating includes small shrinkage cavities ( $< 10 \mu\text{m}$ ) with the periphery/walls enriched with yttrium (appendix A4). In all other phases Y was not detected. The remelting zone of the CMSX-4 contains bright Ta, Si rich particles, which are located in the interdendritic space and has a perfect epitaxial structure (figure 7). Phase composition of the SX coating is very similar to those of the standard vacuum plasma sprayed polycrystalline coating in as-sprayed condition.

[0028] Instead of a similar material as the base material, the coating material can also consist of a Al containing intermetallic material. This can be PtAl or complex alloys like Fe-Cr-Al-alloy known from EP 0 625 585 B1, which are highly oxidation resistant.

[0029] The high level of Al (and/or Si) in the intermetallic material or in the alloy containing intermetallic phase is necessary in order to provide the dense, stable layer of  $\text{Al}_2\text{O}_3$  oxide on the coating surface which effectively presents oxidation of the coating and the substrate.

[0030] The invention is of course not restricted to the exemplary embodiment shown and described.

[0031] Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

## List of Reference Numbers

[0032]

- 1 powder jet
- 2 molten pool
- 3 laser beam
- 4 substrate
- 5 clad

6 dendrite

**Claims**

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1. Gas turbine component consisting of a superalloy base material with a single crystal structure and a protective coating layer,  
wherein the coating layer has a single crystal structure which is epitaxial with the base material.

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2. Gas turbine component as claimed in claim 1,  
wherein the coating consist of an MCrAlY-alloy.

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3. Gas turbine component as claimed in claim 2,  
wherein the coating essentially comprising (measured in % by weight): 25 % Cr; 5,5 % Al; 2,7 % Si; 1 % Ta; 0,5 % Y; rest Ni.

4. Gas turbine component as claimed in claim 1,  
wherein the coating consist of an intermetallic material containing Al.

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5. Gas turbine component as claimed in claim 4,  
wherein the coating consist of PtAl.

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6. Gas turbine component as claimed in claim 1 to 5,  
wherein the base superalloy material essentially comprising (measured in % by weight): 9.3-10.0 Co, 6.4-6.8 Cr, 0.5-0.7 Mo, 6.2-6.6 W, 6.3-6.7 Ta, 5.45-5.75 Al, 0.8-1.2 Ti, 0.07-0.12 Hf, 2.8-3.2 Re, remainder being Ni with impurities.

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7. A method for protecting a gas turbine component consisting of a base superalloy material with a single crystal structure with a protective coating layer,  
wherein the coating is grown epitaxially on the base material and the coating is grown with a single crystal structure.

8. A method as claimed in claim 7,  
wherein the coating is applied by laser cladding.

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9. A method as claimed in claims 7 or 8,  
wherein the coated gas turbine component being treated with diffusion heat at 1080 - 1150°C.

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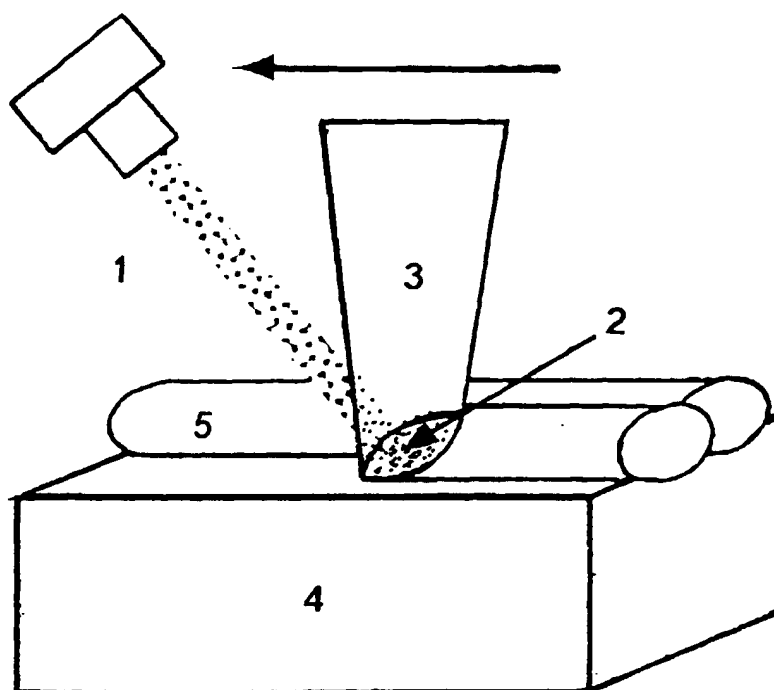
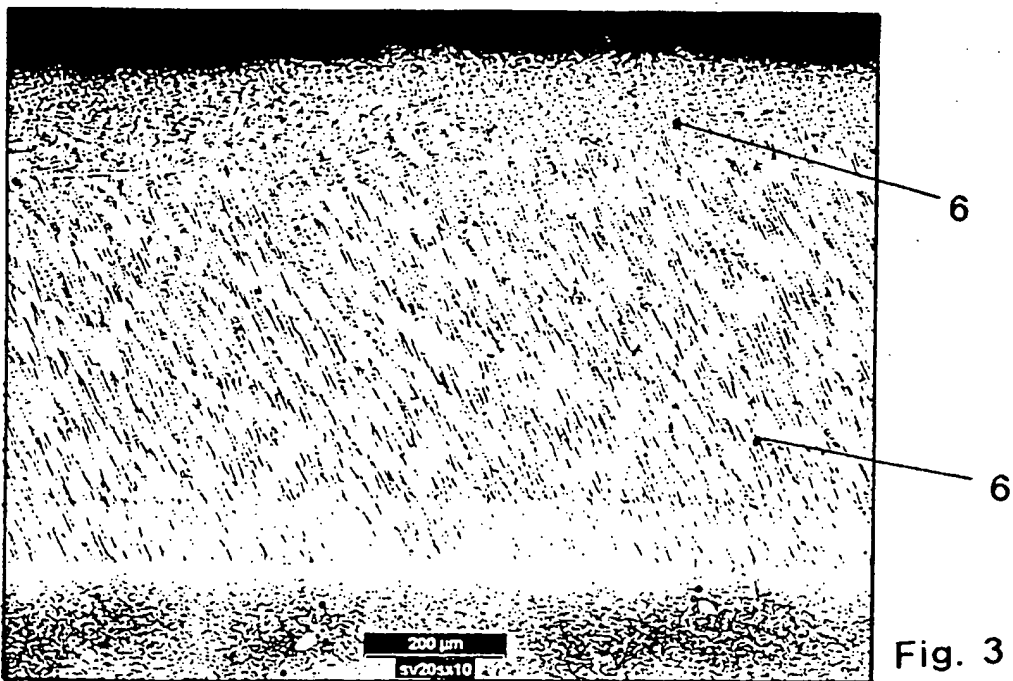
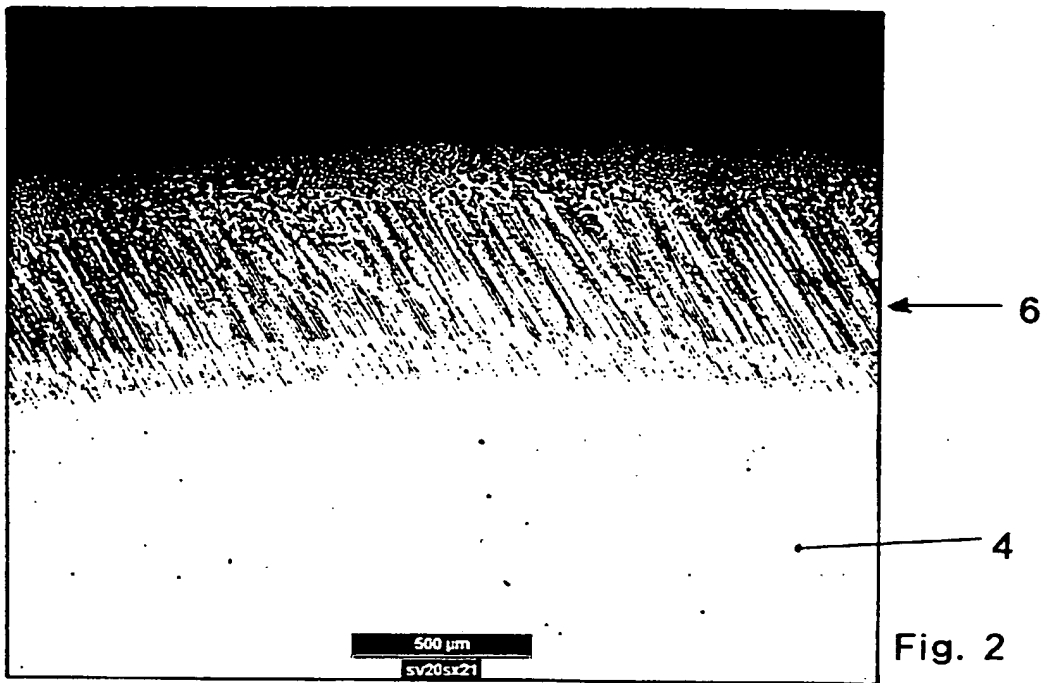


Fig. 1



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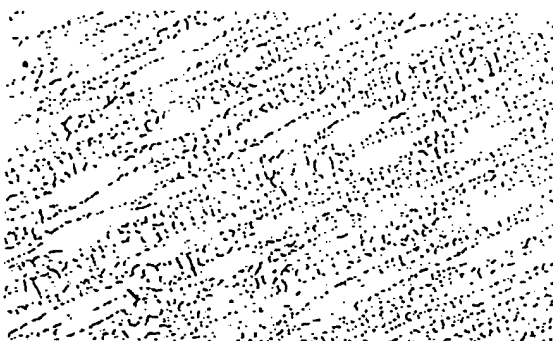


Fig. 4

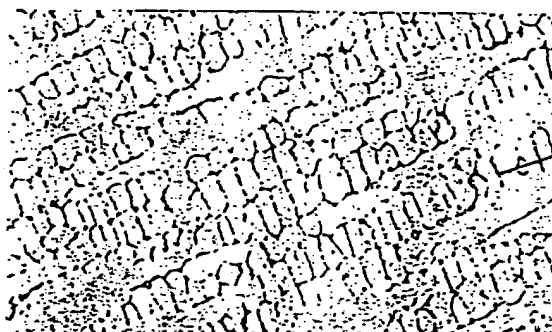


Fig. 5



Fig. 6



Fig. 7





European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 98 81 1125

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 861 927 A (SULZER INNOTECH AG) 2 September 1998	1,6-9	C30B11/00 C30B13/00 C30B29/52 C22C19/05
A	* the whole document *	2	
P,X	EP 0 892 090 A (SULZER INNOTECH AG) 20 January 1999 * the whole document *	1,6-9	
X	EP 0 740 977 A (UNITED TECHNOLOGIES CORP) 6 November 1996	1,7,8	
A	* column 2, line 39 - column 3, line 5 * * column 4, line 14 - line 36 *	2	
A	US 5 312 584 A (FRASIER DONALD J ET AL) 17 May 1994 * column 2, line 28 - line 42 *	1,4,7,8	
A	EP 0 821 076 A (CHROMALLOY UK LTD ;ROLLS ROYCE PLC (GB)) 28 January 1998 * column 3, line 40 - column 4, line 5 * * column 5, line 42 - line 52 *	1,4,5	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	K. HARRIS ET AL: "Development of Two Rhenium-Containing Superalloys for Single-Crystal Blade and Directionally Solidified Vane Applications in Advanced Turbine Engines" JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, vol. 2, no. 4, August 1993, pages 481-487, XP000394071 Ohio, US	1,5,6	C30B C22C
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 21 April 1999	Examiner Lilimpakis, E
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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